SEARCH FOR CHARM IN 250 GeV/c π^-p INTERACTIONS

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The discovery of the ψ and ψ'[1] has led to much speculation that these particles may contain a fourth, "charmed" quark. In the present schemes, the ψ and ψ' would consist of $c\bar{c}$ pairs, and thus have zero units of charm. However a number of other particles containing charm are also postulated.[2] The decay of these particles would often contain a strange particle, with non-leptonic decays expected to dominate. We report here on a search for these charmed particles using neutral strange particle decays in the Fermilab 15-ft bubble chamber.

The 15-ft chamber is an ideal instrument for such a search. Its 4π geometry and large fiducial length (4.7 m) allow for detection of more strange decays, particularly in the forward direction than in smaller chambers (for example, the detection efficiency for finding a $K_S^o \rightarrow \pi^+\pi^-$ decay in the 15' chamber is ~ 90% for this experiment, and only ~ 50% in the 30-inch chamber). In particular, the detection of events with two or more neutral strange decays is greatly enhanced over smaller chambers. It is this advantage that we utilize in the present study. If an associated charm-anticharm pair is produced, both charmed particles may decay into a strange particle plus pions. Thus we search for charm among the events containing two neutral strange particles.

This search has been sensitive to the following specific charmed-particle-production processes:

$$\begin{aligned} \pi^- + p &\rightarrow B_c + M_c + X \\ &\rightarrow M_c + \bar{M}_c + X \\ &\rightarrow B_c + \bar{B}_c + X \end{aligned} \qquad (1)$$

where B_c and M_c stand for charmed baryons and mesons, respectively, and X stands for anything else that may be produced. The decay modes included were:

$$B_c^{\pm} \rightarrow \Lambda(\bar{\Lambda}) + \pi^{\pm}$$
$$B_c^{0} \rightarrow \Lambda(\bar{\Lambda}) + \pi^{+} + \pi^{-}$$
$$M_c^{\pm} \rightarrow K_S^{0} + \pi^{\pm}$$
$$M_c^{0} \rightarrow K_S^{0} + \pi^{+} + \pi^{-}$$

and their antiparticles.

Theoretical estimates of charm-anticharm production would indicate that the cross-section is lower than the sensitivity of this experiment. However, an experimental estimate can be made by comparing with the deuteron-antideuteron production cross section which is of the order of 1 μb[3]. This experiment is unique in that the 4π geometry of the chamber allows us to identify Λ's, thus making us sensitive to decay modes not detected by a recent counter experiment[4]. Our center of mass energy of 21.7 GeV allows detection of higher masses than is possible in lower energy experiments[5]. We therefore feel that these results, although statistically limited, are important.

The data for this study are the preliminary results of a 46,000 picture exposure of $\pi^{-}p$ at 250 GeV/c. In about 40% of this film, 795 events have obtained fits to neutral strange particle hypotheses. These particles have been analyzed using the CERN HYDRA geometry-kinematics system. Of these events, 135 contained two or more fitted neutral strange particles.

The cross section for these events has been determined by weighting the number of events found by the following factors[6]:

a) scanning efficiencies for finding the primary vertex and for finding Vee decays

b) detection efficiencies for missing close-in Vees (all Vees closer than 10 cm to the primary vertex were eliminated from the sample due to large inefficiencies in this region)

c) corrections for neutrals decaying outside the chamber

d) measurement and fitting efficiencies (through the HYDRA system)

e) branching ratios for observable decays of K_S^o's, Λ's and $\bar{\Lambda}$'s

f) the microbarn equivalent, determined from a measurement of the total cross section[7].

The effective mass distributions for $K^o\bar{K}^o$, $K^o\Lambda$, $\bar{K}^o\bar{\Lambda}$, and $\Lambda\bar{\Lambda}$ are shown in Fig. 1. In each case, the dominant feature is peaking near the low mass threshold for the production of the pair. Such threshold enhancements may indicate the existence of non-charmed two strange particle clusters.

In order to enhance the charmed particle signal, we concentrate on those events in which the two-particle mass is considerably above threshold. If the two strange particles come from separate charmed particles, their effective mass will not often be low. For example, a simple calculation for the isotropic decay of two M_c particles (of mass 2.25 GeV, both initially at rest) into $K\pi$ indicates 2/3 of the KK pairs will be above 1.5 GeV. Thus we have selected for special study those events for which the two-strange-particle mass was greater than 150% above threshold.

For the 41 such events in our sample, all charged tracks at the primary vertex were measured and assumed to be pions; 36 of these events were successfully measured.

An inclusive study was made of the decay mode possibilities by combining the candidates for each of the decays in Reactions (2). The mass distributions for $K_S^o\pi$, $\Lambda\pi$ (π^+ and π^- combinations added together), $K_o^S\pi^+\pi^-$ and $\Lambda\pi^+\pi^-$ are shown in Figs. 2 and 3. These plots are weighted for the various efficiencies noted above. The mass resolutions are of the order of 100 MeV (the bin size). The signal for new particle production which would have been accepted was to be a four-standard deviation enhancement in one or two adjacent bins above a smooth background. However, other than a few combinational fluctuations, no statistically significant enhancements are observed.

An upper limit for each decay mode was obtained by assuming four-standard deviations on the total number of events in a given bin. These limits decrease with mass as demonstrated for $\Lambda\pi$ by the insert to Fig. 2. Representative values at the given mass values are as follows:

$K_S^{\,o}\ \pi^{\pm}$	80 μb	2.5 GeV
$\Lambda\ \pi^{\pm}$	40 μb	2.5 GeV
$\bar{\Lambda}\ \pi^{\pm}$	50 μb	2.5 GeV
$K_S^{\,o}\ \pi^{+}\pi^{-}$	80 μb	3.5 GeV
$\Lambda\ \pi^{+}\pi^{-}$	45 μb	3.5 GeV
$\bar{\Lambda}\ \pi^{+}\pi^{-}$	50 μb	3.5 GeV

We have attempted to enhance signals in the mass plots by selecting the charmed-candidate clusters that have a transverse momentum of $p_{\perp} > 1$ GeV. However, due to the resulting paucity of data, nothing was observed with statistical significance.

Another possible decay mode of a charmed particle is into $K^{o}p$. We have measured all primary tracks identified on the scan table as protons in events containing a $K_s^{\,o}$. The $K_s^{\,o}p$ mass distribution for these 23 events shows no statistically significant peaks.

In summary, at our present statistical level we have not seen any evidence for charmed particle production. However, these are preliminary results, and further data and modes of analysis are forthcoming.

We would like to acknowledge the diligent efforts of the 15' bubble chamber staff at Fermilab, and the scanning staffs of both Fermilab and Florida State University. We also appreciate extra help by R. Bates and M. Sokoloff.

REFERENCES

[1]J. J. Aubert et al., Phys. Rev. Lett. 33, 1404 (1974).
J. E. Augustin et al., Phys. Rev. Lett. 33, 1406 (1974).
G. S. Abrams et al., Phys. Rev. Lett. 33, 1453 (1974).

[2]For example, see M. K. Gaillard, B. W. Lee, J. L. Rosner, Rev. Mod. Phys. 47, 277 (1975).

[3]A. S. Carroll et al., "A Survey for Exotic Particles in the M1 Beam," Fermilab proposal, 1975.

[4]B. Gobbi et al., Phys. Rev. Lett. 35, 76 (1975).

[5]C. Baltay et al., Phys. Rev. Lett. 34, 1118 (1975).

[6]See S. Kahn et al., "Neutral Strange Particle Production in π-p Interactions at 250 GeV/c," paper submitted to the Seattle Meeting of the Division of Particles and Fields, 1975.

[7]See S. Hagopian et al., "Topological Cross Sections and Multiplicity Moments for π-p Interactions at 250 GeV/c," paper submitted to the Seattle Meeting of the Division of Particles and Fields, 1975.

FIGURE CAPTIONS

Figure 1: KK, $K\Lambda$, $\bar{K}\bar{\Lambda}$, $\bar{\Lambda}\Lambda$ effective mass distributions.

Figure 2: $K_S^o\pi^+ + K_o^S\pi^-$ and $\Lambda\pi^+ + \Lambda\pi^-$ mass distributions, weighted insert: upper limit cross sections for new particles decaying to $\Lambda\pi$.

Figure 3: $K_S^o\pi^+\pi^-$ and $\Lambda\pi^+\pi^-$ mass distributions, weighted.

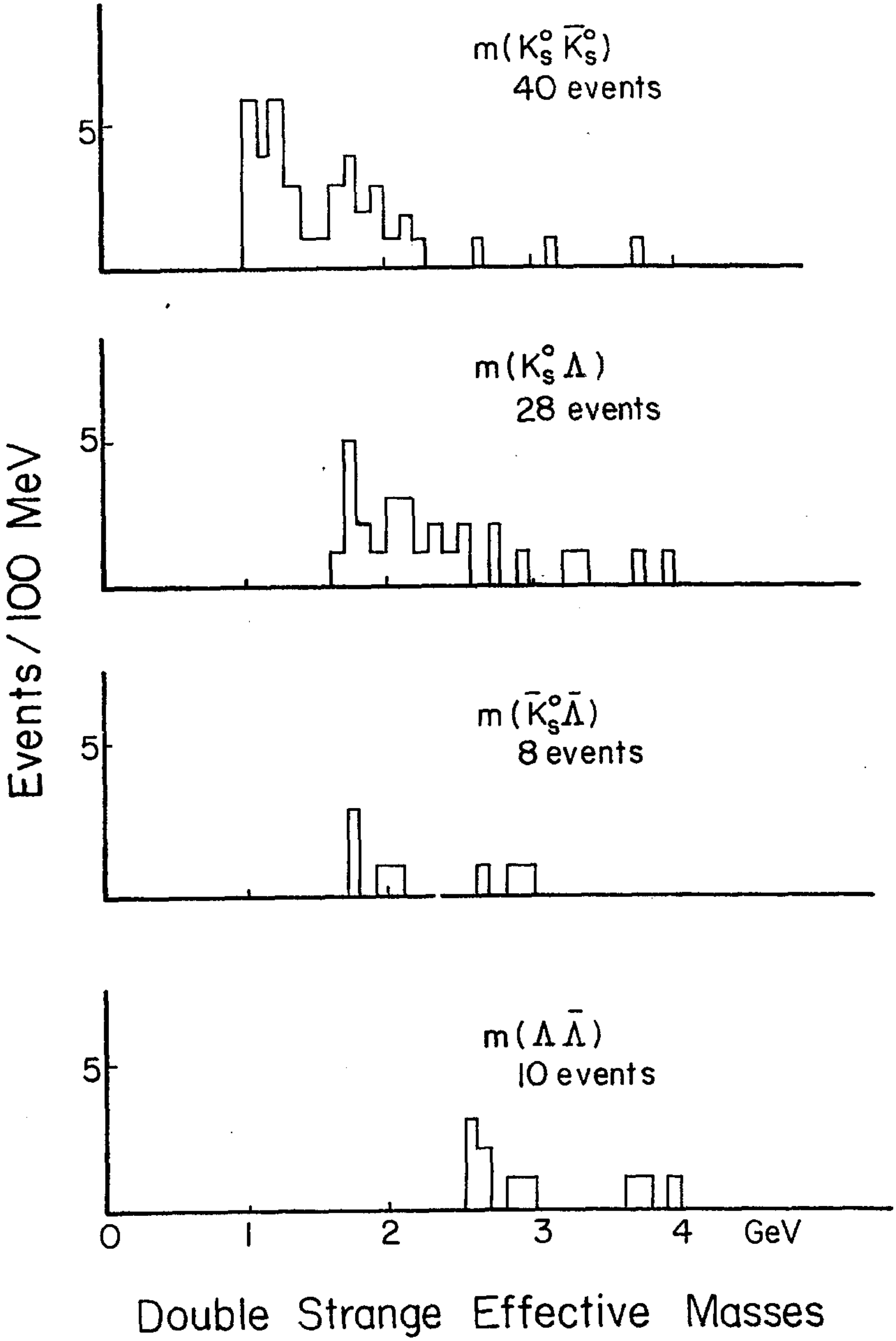
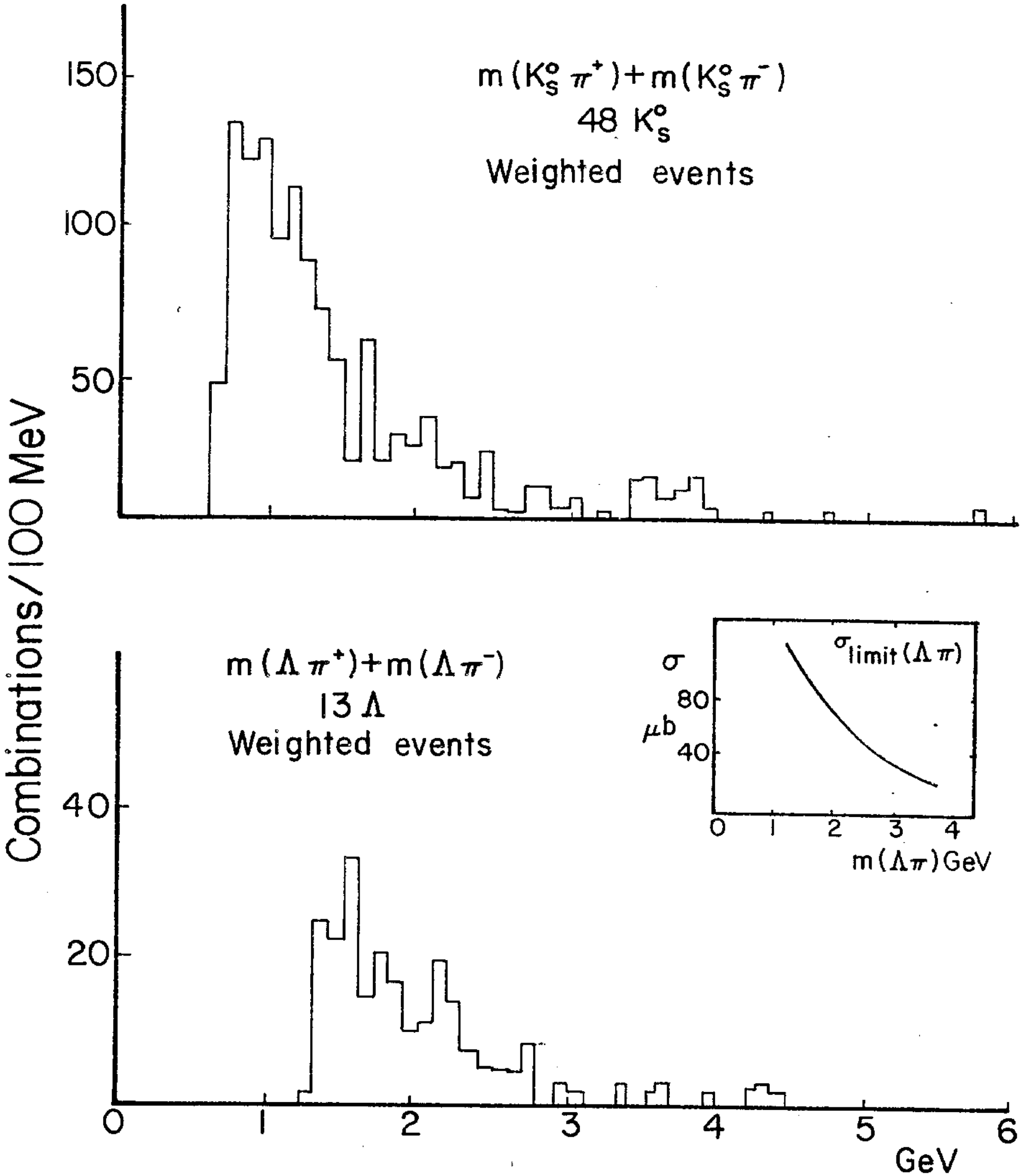
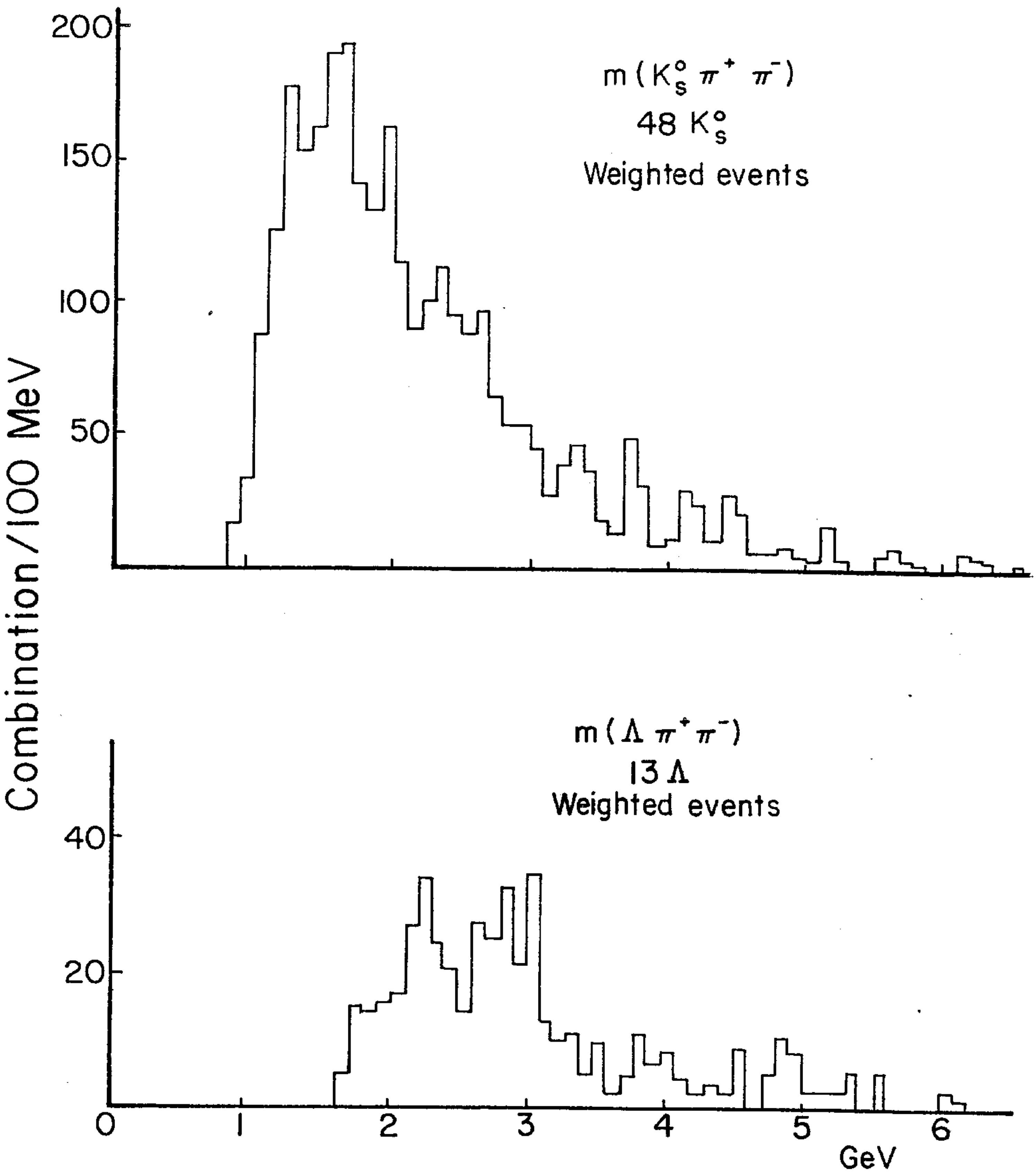

Events / 100 MeV
m($K_s^o \bar{K}_s^o$)
40 events
m($K_s^o \Lambda$)
28 events
m($\bar{K}_s^o \bar{\Lambda}$)
8 events
m($\Lambda \bar{\Lambda}$)
10 events
5
0
1
2
3
4
GeV
Double Strange Effective Masses

Figure 1



$K\pi$ and $\Lambda\pi$ Effective Masses

Figure 2



$K_s^o \pi^+ \pi^-$ and $\Lambda \pi^+ \pi^-$ Effective Masses

Figure 3